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Janowiak

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(54) **BALL PLUNGER FOR USE IN A HYDRAULIC LASH ADJUSTER AND METHOD OF MAKING SAME**

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(Continued)

(52) **U.S. Cl.**
CPC ***F01L 1/24*** (2013.01); ***B21C 23/14*** (2013.01); ***B21C 23/20*** (2013.01); ***F01L 1/2405*** (2013.01);
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CPC F01L 1/2405; F01L 1/24; F01L 2103/00; F01L 1/14; Y10T 29/49304;
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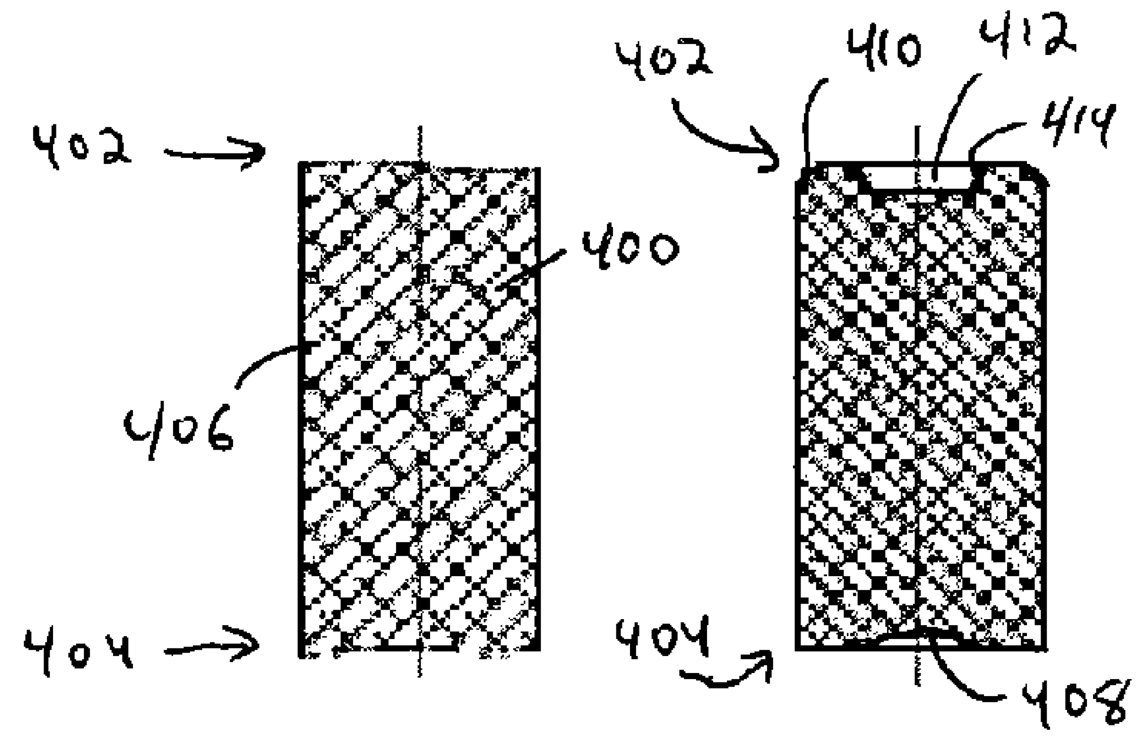
(57) **ABSTRACT**

A method of cold-forming a ball plunger blank includes providing a slug having a generally cylindrical surface extending between a first end and a second end, transferring the slug to a first forming station, at the first forming station forming an indentation in at least one of the first and second ends, and rotating the slug and transferring the slug to a second forming station. The method further includes extruding a first bore through the first end while simultaneously forming a hemispherical surface at the second end, backward extruding a second bore at the first end, and forming a counterbore in the second end.

19 Claims, 5 Drawing Sheets



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Related U.S. Application Data

division of application No. 12/235,919, filed on Sep. 23, 2008.

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B21C 23/14 (2006.01)
B21C 23/20 (2006.01)

(52) **U.S. Cl.**
CPC *F01L 1/14* (2013.01); *F01L 2103/00* (2013.01); *Y10T 29/493* (2015.01); *Y10T 29/49298* (2015.01); *Y10T 29/49304* (2015.01); *Y10T 29/49311* (2015.01); *Y10T 29/49313* (2015.01); *Y10T 29/49995* (2015.01)

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USPC 29/557, 888.43, 888.4, 888.44, 888.451, 29/888.452; 72/354.6, 355.2, 355.6, 358, 72/359, 370.1; 123/90.43, 90.45, 90.46, 123/90.55
See application file for complete search history.

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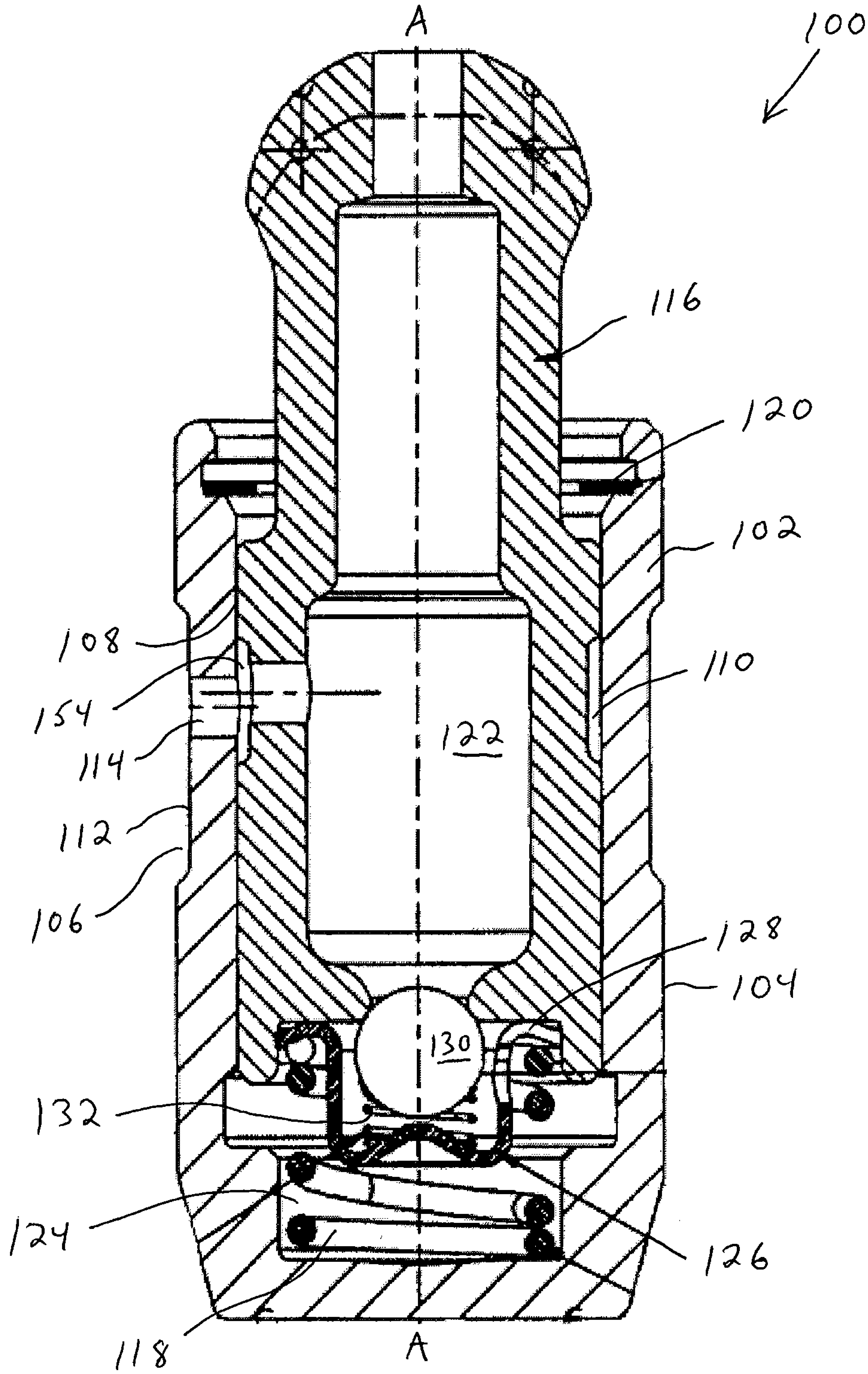

A
100
116
120
102
108
110
154
122
114
112
106
128
104
130
132
124
126
118
A

FIG. 1A

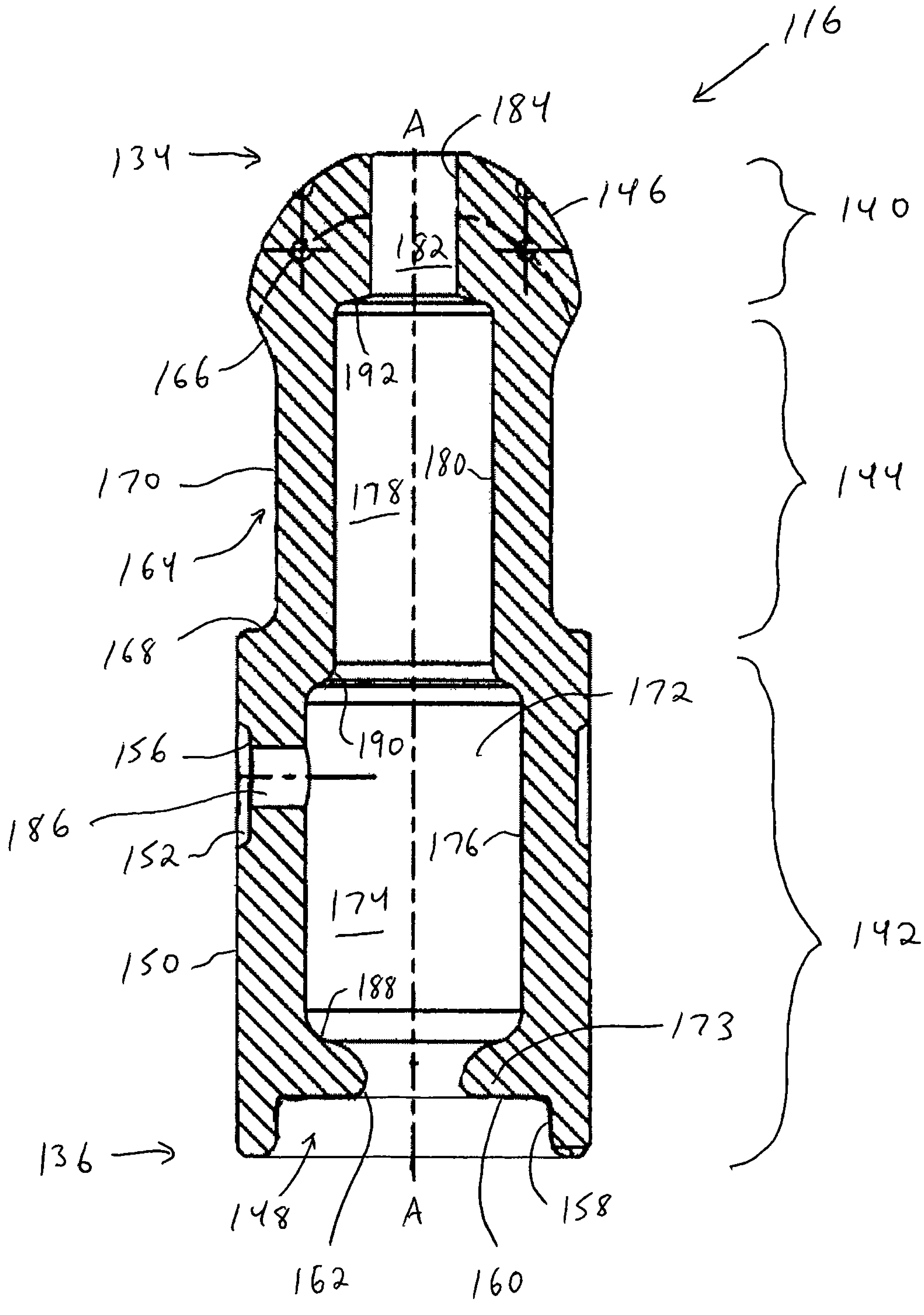
116
A
184
134
146
140
182
166
192
144
180
170
178
164
168
172
156
190
186
176
152
174
142
150
188
173
136
148
A
158
162
160

FIG. 1B

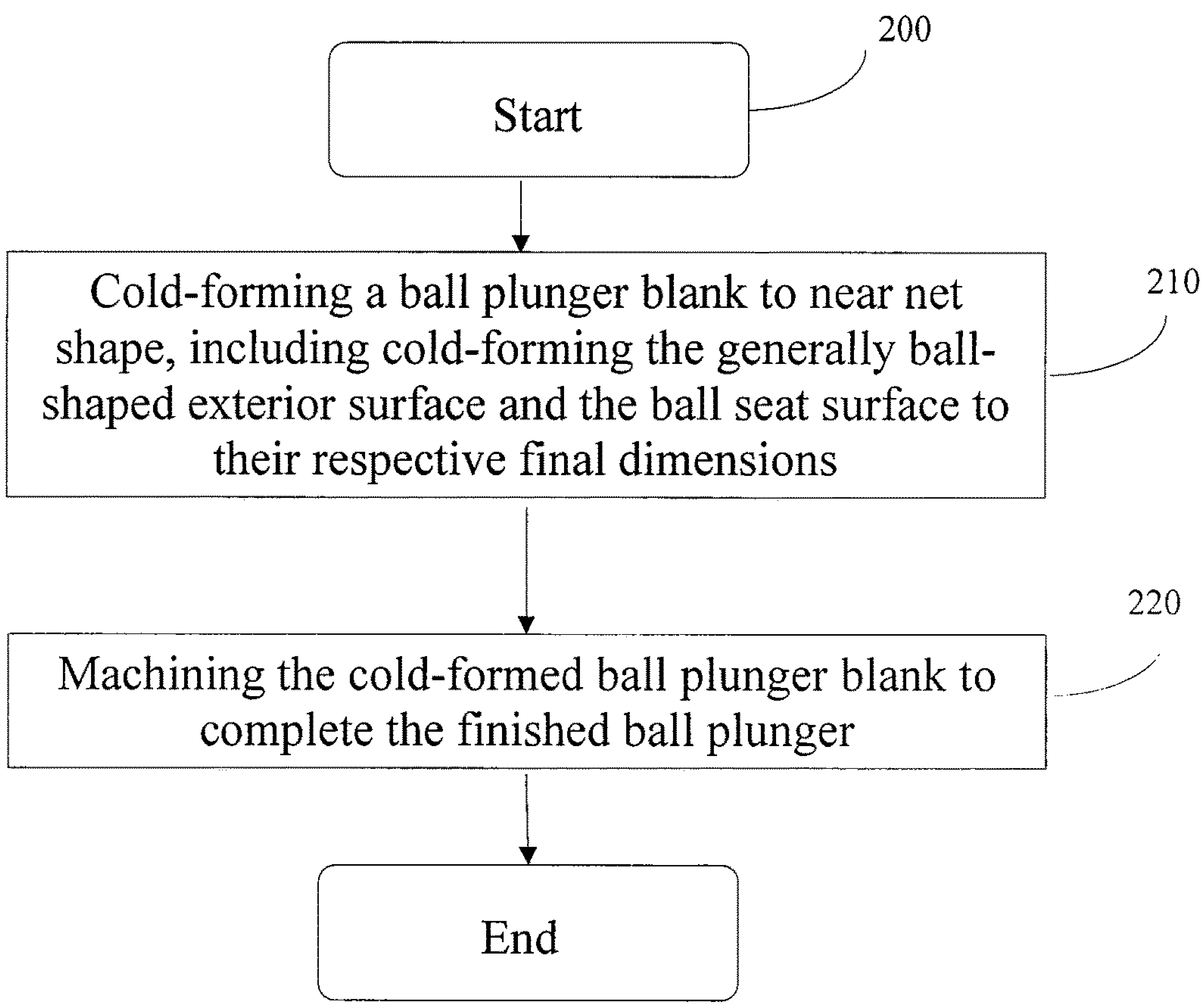
200
Start
210
Cold-forming a ball plunger blank to near net shape, including cold-forming the generally ball-shaped exterior surface and the ball seat surface to their respective final dimensions
220
Machining the cold-formed ball plunger blank to complete the finished ball plunger
End

FIG. 2

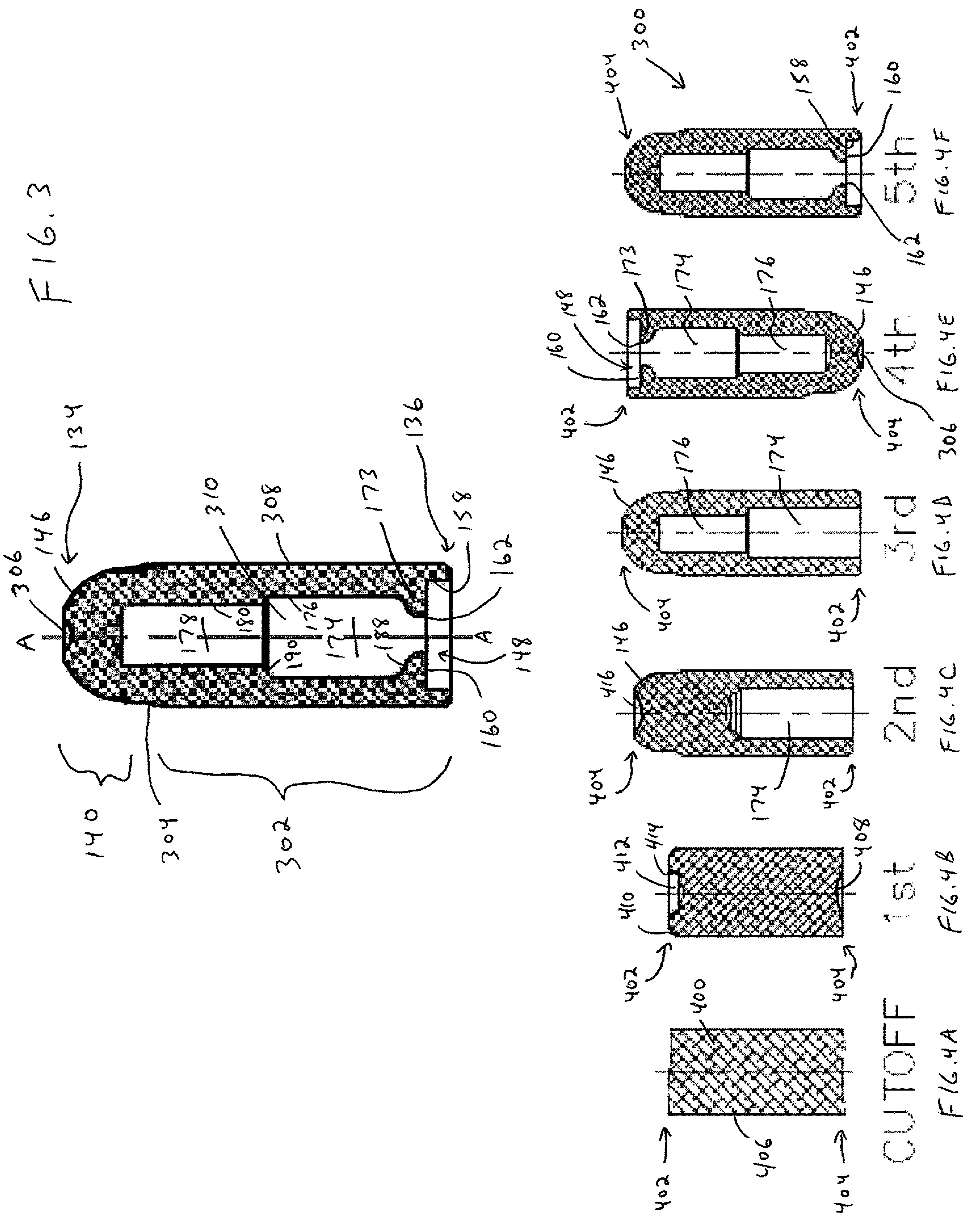

FIG. 3

FIG. 4A

FIG. 4B

FIG. 4C

FIG. 4D

FIG. 4E

FIG. 4F

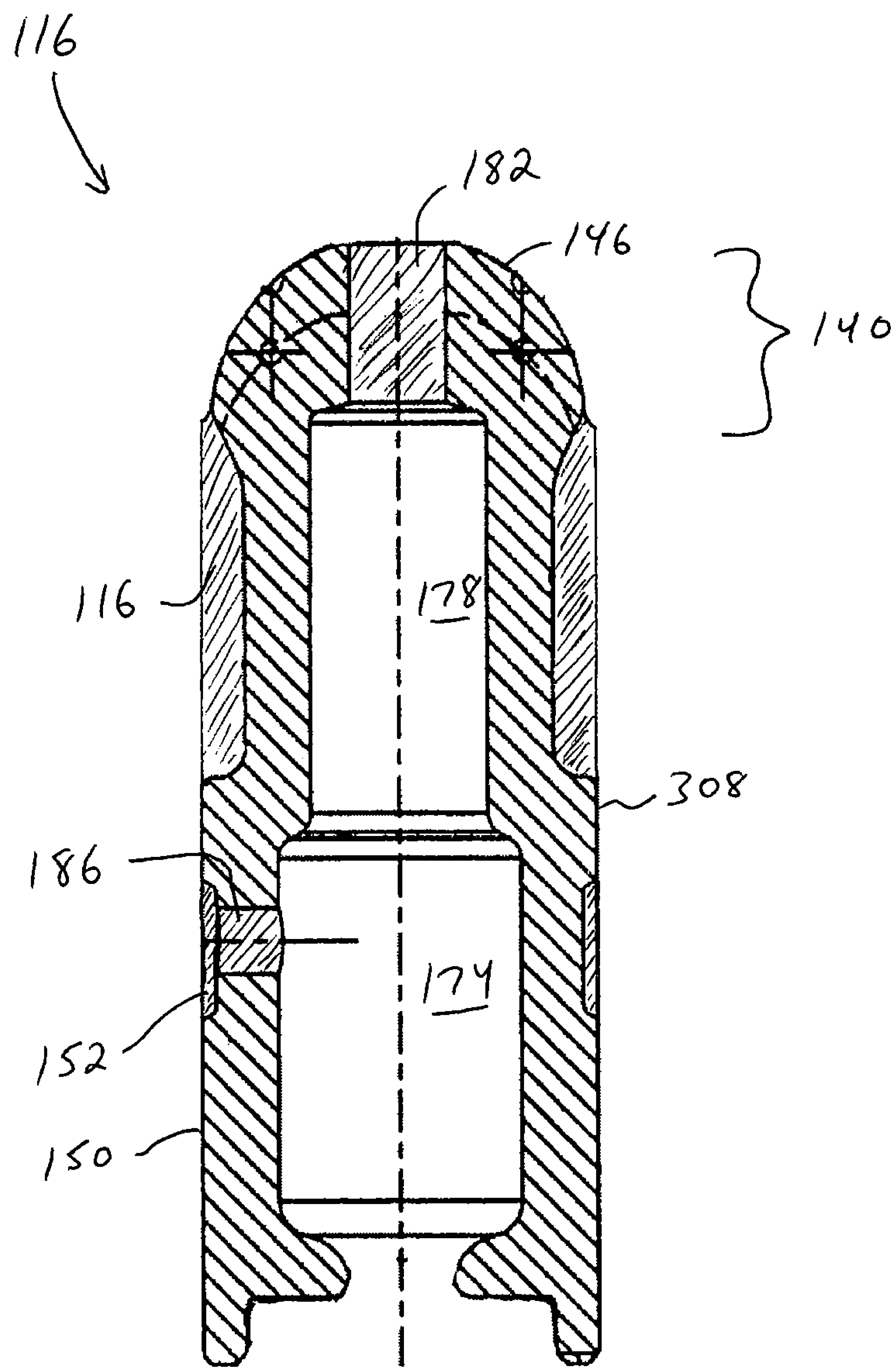

FIG. 5

BALL PLUNGER FOR USE IN A HYDRAULIC LASH ADJUSTER AND METHOD OF MAKING SAME

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/484,701 filed on May 31, 2012, now issued as U.S. Pat. No. 9,388,714, which is a divisional of U.S. patent application Ser. No. 12/235,919, filed on Sep. 23, 2008. The disclosures of the above applications are incorporated by reference herein in their entirety.

FIELD

The present disclosure is directed to a ball plunger for use in a hydraulic lash adjuster and a method of manufacturing the ball plunger.

BACKGROUND

Hydraulic lash adjusters (also sometimes referred to as "lifters") for internal combustion engines have been in use for many years to eliminate clearance (or "lash") between engine valve train components under varying operating conditions, in order to maintain efficiency and to reduce noise and wear in the valve train. Hydraulic lash adjuster operate on the principle of transmitting the energy of the valve actuating cam through hydraulic fluid trapped in a pressure chamber under a plunger. In a Type II valve train, the plunger is known as a "ball plunger" because it has a ball-shaped portion at one end and a seat surface at its other end. During each operation of the cam, as the length of the valve actuating components varies as a result of temperature changes and wear, small quantities of hydraulic fluid are permitted to enter the pressure chamber, or escape therefrom, thus effecting an adjustment in the position of the ball plunger, and consequently adjusting the effective total length of the valve train.

As is known in the art, ball plungers have been initially made in cold-forming machines and then machined to achieve a desired final shape. However, machining processes are time consuming and add to the cost of the finished ball plunger. There are continual efforts to improve upon the processes to manufacture ball plungers, particularly to reduce the machining time and costs associated therewith.

SUMMARY

In one aspect, a method of cold-forming a ball plunger blank is provided. The method includes providing a slug having a generally cylindrical surface extending between a first end and a second end, transferring the slug to a first forming station, at the first forming station forming an indentation in at least one of the first and second ends, and rotating the slug and transferring the slug to a second forming station. The method further includes extruding a first bore through the first end while simultaneously forming a hemispherical surface at the second end, backward extruding a second bore at the first end, and forming a counterbore in the second end.

In another aspect, a method of cold-forming a ball plunger blank using a cold-forming machine having a cutoff station and five forming stations each with a die section and a punch section is provided. The method includes at the cutoff station, shearing wire to a desired length to form a slug having a generally cylindrical surface extending between a first end and a second end, transferring the slug to the first forming station such that the first end faces the die section and the second end faces the punch section, and rotating the slug and transferring the slug to the second forming station such that the first end faces the punch section and the second end faces the die section. The method further includes at the second forming station, extruding a first bore through the first end and forming a hemispherical surface at the second end, at the third forming station, backward extruding a second bore at the first end, at the fourth forming station, forming a counterbore in the second end, and at the fifth forming station, further forming the hemispherical surface to near final dimensions.

Further areas of applicability of the teachings of the present disclosure will become apparent from the detailed description, claims and the drawings provided hereinafter, wherein like reference numerals refer to like features throughout the several views of the drawings. It should be understood that the detailed description, including disclosed embodiments and drawings referenced therein, are merely exemplary in nature intended for purposes of illustration only and are not intended to limit the scope of the present disclosure, its application or uses. Thus, variations that do not depart from the gist of the present disclosure are intended to be within the scope of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

It will be appreciated that the illustrated boundaries of elements in the drawings represent only one example of the boundaries. One of ordinary skill in the art will appreciate that a single element may be designed as multiple elements or that multiple elements may be designed as a single element. An element shown as an internal feature may be implemented as an external feature and vice versa.

Further, in the accompanying drawings and description that follow, like parts are indicated throughout the drawings and description with the same reference numerals, respectively. The figures may not be drawn to scale and the proportions of certain parts have been exaggerated for convenience of illustration.

FIG. **1**A illustrates a cross-sectional view of an exemplary hydraulic lash adjuster **100**;

FIG. **1**B illustrates a detailed cross-sectional view of one embodiment of a ball plunger **116** for use in the exemplary hydraulic lash adjuster **100**;

FIG. **2** illustrates an example method **200** of producing the ball plunger **116** described above and illustrated in FIGS. **1**A and **1**B;

FIG. **3** illustrates a cross-sectional view of one embodiment of a cold-formed ball plunger blank **300** following the cold-forming step (step **210**) described in FIG. **2**;

FIGS. **4**A-**4**F illustrates an exemplary cold-forming, five station slug progression sequence that can be used to form the cold-formed ball plunger blank **300**; and

FIG. **5** illustrates a cross-sectional view of the finished ball plunger **116** following the machining step (step **220**) described in FIG. **2**.

DETAILED DESCRIPTION

Certain terminology will be used in the foregoing description for convenience in reference only and will not be limiting. The terms "upward," "downward," "upper," and "lower" will be understood to have their normal meanings and will refer to those directions as the drawing figures are normally viewed. All foregoing terms mentioned above include the normal derivative and equivalents thereof.

The present application is directed to a ball plunger for use in a hydraulic lash adjuster. The ball plunger is of a one-piece construction that is cold-formed to near net shape, requiring a reduced amount of machining to complete the finished part as compared to prior art ball plungers.

FIG. **1**A illustrates a cross-sectional view of an exemplary hydraulic lash adjuster **100**. The hydraulic lash adjuster **100**, which is of the Type II valve train variety, is shown by way of example only and it will be appreciated that the ball plunger employed therein can be used in any configuration of a hydraulic lash adjuster and is not limited to the configuration of the hydraulic lash adjuster **100** illustrated in FIG. **1**A. The general structure and operation of the hydraulic lash adjuster **100** shown in FIG. **1**A is known to those skilled in the art, and will therefore be described in summary fashion.

As shown in FIG. **1**A, the hydraulic lash adjuster **100** includes a body **102** that is configured to be disposed within a mating bore (not shown) in an engine cylinder head (not shown). The body **102** includes a longitudinal axis A, a first generally cylindrical exterior surface **104** having an outwardly facing groove **106**, and an interior surface **108** that defines a blind bore **110**. The groove **106** is at least partially defined by a second generally cylindrical exterior surface **112** that has an outer diameter that is less than the outer diameter of the first cylindrical exterior surface **104**. Extending radially between the first cylindrical exterior surface **104** and the second cylindrical exterior surface **112** is a fluid port **114** that provides fluid communication between the groove **106** and the blind bore **110**.

The hydraulic lash adjuster **100** also includes a ball plunger **116** disposed in the blind bore **110**. The ball plunger **116**, which will be discussed in more detail below, is configured for reciprocal movement relative to the body **102** along the longitudinal axis A. A plunger spring **118** is disposed within the blind bore **104** underneath the ball plunger **116** and is configured to bias the ball plunger **116** in an upward direction relative to the body **102**. The plunger spring **118** acts at all times to elevate the ball plunger **116** to maintain its engagement with the hemispherical concave surface (not shown) of a rocker arm (not shown). To limit outward movement of the ball plunger **116** relative to the body **102** and retain the ball plunger **116** within to the body **102**, a retaining member **120**, such as a retaining ring or washer, is provided adjacent the upper portion of the body **102**.

With continued reference to FIG. **1**A, the ball plunger **116** itself defines a low pressure fluid chamber **122**, while the body **102** and the lower portion of the ball plunger **116** cooperate with each other to define a high pressure fluid chamber **124** within the blind bore **104** of the body **102**. To control fluid flow between the low fluid pressure chamber **122** and the high pressure fluid chamber **124**, the hydraulic lash adjuster **100** includes a check valve assembly **126** positioned between the plunger spring **118** and the lower portion of the ball plunger **116**. The check valve assembly **126** functions to either permit fluid communication, or to block fluid communication, between the low pressure fluid chamber **122** and the high pressure fluid chamber **124**, in response to the pressure differential between the two fluid chambers **122**, **124**.

As shown in FIG. **1**A, the check valve assembly **126** includes a retainer **128** that is in engagement with a lower portion of the ball plunger **116**, a check ball **130**, and a check ball spring **132** that is disposed between the retainer **128** and the check ball **130**. The check ball spring **132** is configured to bias the check ball **130** in an upwards direction towards the ball plunger **116**, and is therefore commonly referred to by those skilled in the art as a "normally biased closed" check valve assembly.

Illustrated in FIG. **1**B is a detailed cross-sectional view of the ball plunger **116** employed in the exemplary hydraulic lash adjuster **100** illustrated in FIG. **1**A. It will be appreciated that the ball plunger **116** illustrated in FIGS. **1**A and **1**B is shown by way of example only and is not limited to the configuration shown in these drawings.

With reference to FIG. **1**B, the ball plunger **116** is a generally tubular member having a first end **134** that extends to a second end **136** along a longitudinal axis A, a ball portion **140** adjacent to the first end **134**, a body portion **142** adjacent to the second end **136**, and a stem portion **144** disposed between the ball portion **140** and the body portion **142**. The ball portion **140** of the ball plunger **116** includes a generally ball-shaped or hemispherical outer surface **146**, which is configured to engage and pivot about the generally hemispherical concave surface (not shown) of a rocker arm (not shown).

The body portion **142** of the ball plunger **116** includes a counterbore **148** configured to receive the check valve assembly **126**, a first generally cylindrical exterior surface **150**, and a radially outward facing groove **152** formed in the cylindrical exterior surface **150**. The groove **152** cooperates with the interior surface **108** of the body **102** to form a fluid collector channel **154** (see FIG. **1**A) and is at least partially defined by a second generally cylindrical exterior surface **156** that has an outer diameter that is less than the outer diameter of the first cylindrical exterior surface **150**.

With continued reference to FIG. **1**B, the counterbore **148** is defined by a generally cylindrical interior surface **158**, a flat annular surface **160** that is generally perpendicular to the axis A and extends from the cylindrical interior surface **158**, and a rounded annular surface **162** that extends from the flat annular surface **160**. The flat annular surface **160** is sized to receive the retainer **128** of the check valve assembly **126** and will sometimes be referred to herein as the "retainer receiving surface **160**." The rounded annular surface **162** is sized to receive the check ball **130** of the check valve assembly **126**, such that when the check ball **130** engages the rounded annular surface **162**, a fluid tight seal is created between the check ball **130** and the rounded annular surface **162** (see FIG. **1**A). Hence, the rounded annular surface **162** may also be referred to herein as the "ball seat **162**" or the "ball seat surface **162**." Although the ball seat surface **162** in the illustrated embodiment of the ball plunger **116** is a rounded annular surface, it will be appreciated that the ball seat surface **162** can be an annular frusto-conical surface, so long as an appropriate fluid tight seal is created between the check ball **130** and the ball seat surface **162**.

The stem portion **144** of the ball plunger **116** is defined by a groove **164** that separates the ball portion **140** from the body portion **142** of the ball plunger **116**. The groove **164** is at least partially defined by a frusto-conical surface **166** that extends from the hemispherical exterior surface **146** towards the body portion **142**, a transition surface **168** that extends from the first cylindrical exterior surface **150** towards the ball portion **140**, and a generally cylindrical exterior surface **170** disposed between the frusto-conical surface **166** and the transition surface **168**. In the illustrated example, the transition surface **168** includes a frusto-conical surface and a curved surface that is convex with respect to the longitudinal axis A. However, it will be appreciated that the transition surface **168** can include an annular surface that is generally perpendicular to the axis A, a frusto-conical surface, a curved surface that is concave or convex with respect to the longitudinal axis A, or any combination thereof.

With continued reference to FIG. 1B, disposed within the ball plunger **116** between the ball seat surface **162** and the hemispherical exterior surface **146** is an axially extending passage **172**. Provided between the passage **172** and the counterbore **148** is a shoulder **173** that includes, among other surfaces, the retainer receiving surface **160** and the ball seat surface **162**.

Generally, the passage **172** (which also corresponds to the low pressure fluid chamber **122** as shown in FIG. 1A) includes a first axially extending bore **174** defined by a first generally cylindrical interior surface **176** having a first diameter, a second axially extending bore **178** defined by a second generally cylindrical interior surface **180** having a second diameter that is less than the first diameter of the first cylindrical interior surface **176**, and a third axially extending bore **182** defined by a third generally cylindrical interior surface **184** having a third diameter that is less than the second diameter of the second cylindrical interior surface **180**. Extending radially between the first cylindrical interior surface **176** and the second cylindrical exterior surface **156** is a plunger fluid port **186** that provides fluid communication between the groove **152** and the first bore **174**.

The passage **172** is also defined by three transition surfaces—a first transition surface **188** that transitions the ball seat surface **162** to the first cylindrical interior surface **176**, a second transition surface **190** that transitions the first cylindrical interior surface **176** to the second cylindrical interior surface **180**, and a third transition surface **192** that transitions the second cylindrical interior surface **180** to the third cylindrical interior surface **184**. It will be appreciated that each of these transition surfaces can include an annular surface that is generally perpendicular to the axis A, a frusto-conical surface, a curved surface that is concave or convex with respect to the longitudinal axis A, or any combination thereof.

Illustrated in FIG. **2** is an example method **200** of producing the ball plunger **116** described above and illustrated in FIGS. **1**A and **1**B. As shown in FIG. **2**, the method **200** includes two general steps—i) cold-forming a ball plunger blank to near net shape, including cold-forming the generally ball-shaped outer surface **146** and the ball seat surface **162** to their respective final dimensions (step **210**) and ii) machining the cold-formed ball plunger blank to complete the finished ball plunger **116** (step **220**). As used herein, the term "cold-forming" and its derivatives, is intended to encompass what is known in the art as "cold forging," "cold heading," and "deep drawing." As used herein, the term "machining" means the use of a chucking machine, drilling machine, turning machine, grinding machine, or broaching machine to remove material.

Illustrated in FIG. **3** is a cross-sectional view of one embodiment of a cold-formed ball plunger blank **300** that is the result of the cold-forming step (step **210**) described above. As shown in FIG. **3**, the cold-formed ball plunger blank **300** is near net shape as compared to the finished ball plunger **116**. For consistency purposes, structural features that are common between the cold-formed ball plunger blank **300** and the finished ball plunger **116** will be indicated with the same reference numerals, while different structural features will be indicated with new reference numerals.

As shown in FIG. **3**, the cold-formed ball plunger blank **300** includes a generally cup-shaped member having a first end **134** extending toward a second end **136** along a longitudinal axis A, a ball portion **140** adjacent the first end **134**, an extended body portion **302** adjacent the second end **136**, and a transition surface **304** separating the ball portion **140** from the extended body portion **302**. The ball portion **140** includes a generally ball-shaped or hemispherical outer surface **146** and a dimple or indentation **306** extending therefrom. In the illustrated embodiment, the transition surface **304** includes a frusto-conical surface. However, it will be appreciated that the transition surface **304** can include an annular surface that is generally perpendicular to the axis A, a frusto-conical surface, a curved surface that is concave or convex with respect to the longitudinal axis A, or any combination thereof.

The extended body portion **302** of the cold-formed ball plunger blank **300** includes a counterbore **148** and a generally cylindrical exterior surface **308**. The counterbore **148** is defined by a generally cylindrical interior surface **158**, a flat annular surface **160** that is generally perpendicular to the axis A and extends from the cylindrical interior surface **158** (also referred to as the "retainer receiving surface **160**"), and a rounded annular surface **162** (also referred to as the "ball seat **162**" or the "ball seat surface **162**") that extends from the retainer receiving surface **160**.

With continued reference to FIG. **3**, disposed within the cold-formed ball plunger blank **300** is an axially extending bore or cavity **310** extending from the ball seat surface **162** towards the ball portion **140**. Provided between the cavity **310** and the counterbore **148** is a shoulder **173** that includes, among other surfaces, the retainer receiving surface **160** and the ball seat surface **162**.

Generally, the cavity **310** includes a first bore **174** defined by a first generally cylindrical interior surface **176** having a first diameter and a second bore **178** defined by a second generally cylindrical interior surface **180** having a second diameter that is less than the first diameter of the first cylindrical interior surface **176**.

The cavity **310** is also defined by two transition surfaces—a first transition surface **188** that transitions the ball seat surface **162** to the first cylindrical interior surface **176** and a second transition surface **190** that transitions the first cylindrical interior surface **176** to the second cylindrical interior surface **180**. It will be appreciated that each of these transition surfaces can include an annular surface that is generally perpendicular to the axis A, a frusto-conical surface, a curved surface that is concave or convex with respect to the longitudinal axis A, or any combination thereof.

The cold-formed ball plunger blank **300** can be formed in a variety of cold-forming machines. Suitable examples of cold-forming machines that can be used to form the cold-formed ball plunger blank **300** include Waterbury and National Machinery cold-forming machines. Generally, cold-forming machines include a cut-off station for cutting metal wire to a desired length to provide an initial workpiece (also known as a "slug") and multiple progressive forming stations that include multiple spaced-apart die sections and a reciprocating gate having multiple punch sections, each of which cooperates with a respective die section to form a die cavity. A conventional transfer mechanism moves the slug in successive steps from the cut-off station to each of the forming stations in a synchronized fashion and is also capable of rotating the slug 180 degrees as it is being transferred from one station to another. As cold-forming machines are well known in the art, no further description is necessary.

In one embodiment, the cold-formed ball plunger blank **300** is formed in a five station, cold-forming machine (not shown). It will, however, be appreciated that the cold-formed ball plunger blank **300** can be produced in a different number of forming stations.

Illustrated in FIGS. **4A-4E** is an exemplary cold-forming, five station slug progression sequence that can be used to form the cold-formed ball plunger blank **300**. Each figure represents the state of the slug at an end-of-stroke tool position. It will be appreciated that this slug progression sequence is merely one example of a cold-forming slug progression sequence and that other slug progression sequences are possible.

The exemplary slug progression sequence begins with shearing wire to a desired length at the cut-off station to provide an initial slug **400**, which will be described with reference to a first end **402**, a second end **404**, and a cylindrical surface **406** that extends therebetween as shown in FIG. **4A**. At this stage, the ends of the slug **400** have irregularities or unevenness inherent in the shearing process. The slug **400** is then transferred to the first forming station where its first end **402** faces the die section and its second end **404** faces the punch section.

At the first forming station, the slug **400** is squared and a slight indentation **408** is formed in the second end **404** at the punch section of the cold-forming machine as shown in FIG. **4B**. At the die section of the cold-forming machine, a chamfer **410** is simultaneously formed between the first end **402** and the cylindrical surface **406** of the slug **400**. Additionally, at the die section, a deeper indentation **412** is formed in the first end **402** of the slug **400** along with a chamfer **414** formed between the indentation **412** and the first end **402**. The indentation **412** serves to properly center and guide the punch from the second forming station, which will be described in further detail below. The slug **400** is then rotated 180 degrees and transferred to the second forming station where its first end **402** faces the punch section and its second end **404** faces the die section.

At the second forming station, the first bore **174** is extruded through the first end **402** of the slug **400** to near final dimensions at the punch section of the cold-forming machine as shown in FIG. **4C**. Simultaneously, at the die section of the cold-forming machine, the generally hemispherical surface **146** is beginning to be formed at the second end **404** of the slug **400**. Additionally, a slight indentation **416** is formed in the second end **404** of the slug **400**. The indentation **416** serves to properly center and guide the punch from the fourth forming station, which will be described in further detail below. The slug **400** is then transferred to the third forming station where its second end **404** faces the punch section and its first end **402** faces the die section.

At the third forming station, the second bore **176**, having a diameter less than the first bore **174**, is backward extruded at the first end **402** of the slug **400** to near final dimensions at the punch section of the cold-forming machine as shown in FIG. **4D**. Simultaneously, at the die section of the cold-forming machine, the hemispherical surface **146** is formed at the second end **404** of the slug **400** to near final dimensions. The slug **400** is then rotated 180 degrees and transferred to the fourth forming station where its second end **404** faces the punch section and its first end **402** faces the die section.

At the fourth forming station, the hemispherical surface **146** is formed to near final dimensions and the dimple **306** is formed in the center-point of the hemispherical surface **146** by the punch section of the cold-forming machine as shown in FIG. **4E**. Simultaneously, at the die section of the cold-forming machine, a counterbore **148**, having a diameter greater than the first bore **174**, is formed in the second end **404** of the slug **400**. Due to this diametrical difference, the die that forms the counterbore **148** upsets the wall defining the first bore **174** and thereby forms the shoulder **173** that defines the retainer receiving surface **160** and the ball seat surface **162** to near final dimensions. The slug **400** is then rotated 180 degrees and transferred to the fifth forming station where its first end **402** faces the punch section and its second end **404** faces the die section.

At the fifth forming station, as shown in FIG. **4F**, the slug **400** is formed to its final dimensions, including overall length and the hemispherical surface **146** being formed to its final dimensions. Also, the cylindrical interior surface **158**, the retainer receiving surface **160**, and the ball seat surface **162** are coined to their respective final dimensions by the punch section of the cold-forming machine. At the conclusion of the fifth forming station, the cold-formed ball plunger blank **300** is completed and includes all of the structural features shown in FIG. **3**.

As discussed above, the cold-formed ball plunger blank **300** includes all of the structural features of the finished ball plunger **116** described above and illustrated in FIGS. **1A** and **1B**, with the exception of several structural features. To complete the method **200** of producing the finished ball plunger **116** described above and illustrated in FIGS. **1A** and **1B**, the cold-formed ball plunger blank **300** is machined to form the remaining structural features as discussed above and shown in FIG. **2**.

The machining step (step **220**) will be discussed with reference to FIG. **5** where the shaded areas of the finished ball plunger **116** represent the material removed from the cold-formed ball plunger blank **300** as a result of the machining step. As shown in FIG. **5**, the groove **164** is machined into the extended body portion **302** and a portion of the hemispherical surface **146** and the groove **152** is machined into the first cylindrical exterior surface **150**. Additionally, the third bore **182** is drilled into the ball portion **140**, such that it communicates with the second bore **178**, and the plunger fluid port **186** is drilled into the body portion **142** such that it communicates with the first bore **174**. It will be appreciated that these machining operations can be performed one at a time, in combination with one or more other machining operations, or all together in any sequence.

Unlike prior art ball plungers, the ball plunger **116** described above is cold formed to near net shape (including the cold formation to final dimensions of the ball portion **140** and the ball seat surface **162**), thereby reducing the machine time to complete a finished ball plunger and thus reducing manufacturing cost of the finished ball plunger. Additionally, when compared to plunger designs that require the use of a seat insert and seal, these parts along with the associated assembly time and costs are eliminated.

For the purposes of this disclosure and unless otherwise specified, “a” or “an” means “one or more.” To the extent that the term “includes” or “including” is used in the specification or the claims, it is intended to be inclusive in a manner similar to the term “comprising” as that term is interpreted when employed as a transitional word in a claim. Furthermore, to the extent that the term “or” is employed (e.g., A or B) it is intended to mean “A or B or both.” When the applicants intend to indicate “only A or B but not both” then the term “only A or B but not both” will be employed. Thus, use of the term “or” herein is the inclusive, and not the exclusive use. See, Bryan A. Garner, A Dictionary of Modern Legal Usage 624 (2d. Ed. 1995). Also, to the extent that the terms “in” or “into” are used in the specification or the claims, it is intended to additionally mean “on” or “onto.”

Furthermore, to the extent the term "connect" is used in the specification or claims, it is intended to mean not only "directly connected to," but also "indirectly connected to" such as connected through another component or multiple components. As used herein, "about" will be understood by persons of ordinary skill in the art and will vary to some extent depending upon the context in which it is used. If there are uses of the term which are not clear to persons of ordinary skill in the art, given the context in which it is used, "about" will mean up to plus or minus 10% of the particular term. From about X to Y is intended to mean from about X to about Y, where X and Y are the specified values.

While the present application illustrates various embodiments, and while these embodiments have been described in some detail, it is not the intention of the applicant to restrict or in any way limit the scope of the claimed invention to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention, in its broader aspects, is not limited to the specific details and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of the applicant's claimed invention. Moreover, the foregoing embodiments are illustrative, and no single feature or element is essential to all possible combinations that may be claimed in this or a later application.

It should be understood that the mixing and matching of features, elements, methodologies and/or functions between various examples may be expressly contemplated herein so that one skilled in the art would appreciate from the present teachings that features, elements and/or functions of one example may be incorporated into another example as appropriate, unless described otherwise above.

What is claimed is:

1. A method of cold-forming a ball plunger blank comprising the steps of:
- providing a slug having a generally cylindrical surface extending between a first end and a second end;
- transferring the slug to a first forming station;
- at the first forming station, forming an indentation in at least one of the first and second ends;
- rotating the slug and transferring the slug to a second forming station;
- extruding a first bore through the first end while simultaneously forming a hemispherical surface at the second end;
- backward extruding a second bore at the first end; and
- forming a counterbore in the second end.

2. The method of claim **1**, wherein the step of forming an indentation includes forming a slight indentation in the second end.

3. The method of claim **1**, wherein the step of forming an indentation includes forming an indentation in the first end.

4. The method of claim **1**, further comprising, at the first forming station, forming at least one chamfer at the first end.

5. The method of claim **4**, wherein the step of forming at least one chamfer includes forming a chamfer between the first end and the cylindrical surface simultaneously with the step of forming the at least one indentation.

6. The method of claim **4**, wherein the step of forming at least one chamfer includes forming a chamfer between the at least one indentation and the first end.

7. The method of claim **1**, wherein the step of rotating the slug comprises rotating the slug approximately 180°, wherein the first and second ends switch positions.

8. The method of claim **1**, further comprising rotating the slug and transferring the slug to the third forming station.

9. The method of claim **8**, further comprising:
- at a third forming station, further forming the hemispherical surface while simultaneously backward extruding the second bore.

10. The method of claim **9**, further comprising rotating the slug and transferring the slug to a fourth forming station.

11. The method of claim **1**, further comprising further forming the hemispherical surface while simultaneously extruding the second bore.

12. The method of claim **10**, further comprising at the fourth forming station, further forming the hemispherical surface to near final dimensions while simultaneously forming the counterbore.

13. The method of claim **1**, further comprising further forming the hemispherical surface to near final dimensions while simultaneously forming the counterbore.

14. The method of claim **13**, further comprising rotating the slug and transferring the slug to a fifth forming station.

15. The method of claim **14**, further comprising at the fifth forming station, forming the hemispherical surface to final dimensions.

16. The method of claim **15**, further comprising at the fifth forming station, forming a ball seat surface and a retainer receiving surface at the first end.

17. A method of cold-forming a ball plunger blank using a cold-forming machine having a cutoff station and five forming stations each with a die section and a punch section, the method comprising:
- at the cutoff station, shearing wire to a desired length to form a slug having a generally cylindrical surface extending between a first end and a second end;
- transferring the slug to the first forming station such that the first end faces the die section and the second end faces the punch section;
- rotating the slug and transferring the slug to the second forming station such that the first end faces the punch section and the second end faces the die section;
- at the second forming station, simultaneously extruding a first bore through the first end and forming a hemispherical surface at the second end;
- at the third forming station, backward extruding a second bore at the first end;
- at the fourth forming station, forming a counterbore in the second end; and
- at the fifth forming station, further forming the hemispherical surface to near final dimensions.

18. The method of claim **17**, further comprising:
- at the third forming station, further forming the hemispherical surface while simultaneously backward extruding the second bore; and
- at the fourth forming station, further forming the hemispherical surface to near final dimensions while simultaneously forming the counterbore.

19. The method of claim **17**, further comprising:
- transferring the slug to the third forming station such that the first end faces the punch section and the second end faces the die section;
- rotating the slug and transferring the slug to the fourth forming station such that the first end faces the die section and the second end faces the punch section; and
- rotating the slug and transferring the slug to the fifth forming station such that the first end faces the punch section and the second end faces the die section.

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